MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

EMG4096 – RADAR SYSTEMS DESIGN AND ANALYSIS
(TE)

17 OCTOBER 2019
2:30 p.m – 4:30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of 7 pages with 3 Questions only .
2. The student is required to answer all questions in the this question paper. Each question carries a particular marks and the distribution of the marks is given .
3. Please write all your answers in the Answer Booklet provided .

Question 1

(a) A C-band Pulse Doppler radar system is designed for operation in an air traffic control tower. The system parameters are listed in the table below.

Operating Frequency	5.3 GHz
Maximum detection range	100 km
Range Resolution	60 m
Antenna Gain	28 dBi
Transmitted Power	20 kW
Target Radar Cross Section	10 m^2

Calculate the following:

(i) Pulse repetition frequency (PRF) if range measurement must be unambiguous.

[2 marks]

(ii) For the PRF in part (i) above, what is the maximum Doppler frequency allow in this system

[2 marks]

(iii) Pulse Width if the range resolution is as listed in table above.

[2 marks]

(iv) Received power at distance of 100 km.

[4 marks]

(b) A Frequency Modulation Continuous Wave (FMCW) radar operates at 9.6 GHz. Saw tooth modulation is used in this radar system. The frequency increases at a rate of 1 GHz/s for 200 ms and then returns to its original value after 200 ms and starts the new cycle again.

(i) Sketch the FMCW waveform with frequency versus time.

[5 marks]

(ii) Show that the beat freqeuncy of the return signal of the fixed target can be written as below.

$$f_{IF} = \frac{4RB}{cT}$$

where f_{IF} is the beat frequency, R is the distance bewteen radar and target, B is the bandwidth of the system, c is speed of light and T is the period of FMCW signal.

[4 marks]

Continued ....

(iii) What is the beat frequency of the echo from a fixed target at a range of 2000 m?

[2 marks]

(iv) What is the beat frequency components if the target is located at 2000 m and closing at a rate of 100 m/s?

[4 marks]

(v) Sketch the return signal for Q1 (b) (iii) and Q1 (b) (iv)

[5 marks]

(c) What is the main function of a Moving Target Indicator (MTI)?

Name one of the components/modules that can be used to implemet the MTI filter.

[4 marks]

(d) A radar uses two *PRF*s with stagger ratio 63/64. If the first *PRF* is 1000Hz, compute the blind speeds for both *PRF*s and for the resultant composite *PRF*. Assume $\lambda = 1$ cm.

[6 marks]

Question 2

(a) The stabilized cylinder target can be modeled using Chi-Square PDF with $\sigma_{ave} = 2$ and Chi-Square model of degree 8.

[The PDF of Chi-square is given as $p(\sigma,k) = \dfrac{k}{\Gamma(k)\sigma_{ave}}\left(\dfrac{k\sigma}{\sigma_{ave}}\right)^{k-1} e^{-(k\sigma/\sigma_{ave})}$]

(i) Express the probability density function as describe above.

[5 marks]

(ii) Calculate the probability of getting RCS = $1.2 \pm 0.01\,\text{m}^2$.

[5 marks]

Continued ....

(b) The azimuth error signal for a monopulse system is observed as $\frac{\Delta}{\Sigma} = 0.35$ at φ_o=0.1 radian. Estimate the target angular position. The graph for Difference-to-sum ratio is shown in figure below.

[The difference to sum ratio is given as $\frac{\Delta(\varphi)}{\sum(\varphi)} = \frac{\sin c(\varphi - \varphi_o) - \sin c(\varphi + \varphi_o)}{\sin c(\varphi - \varphi_o) + \sin c(\varphi + \varphi_o)}$]

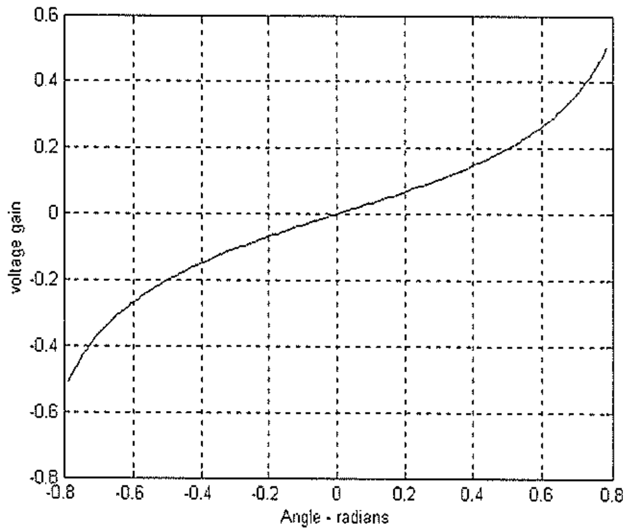

Figure Q2.1: Difference-to-sum ratio

[10 marks]

(c) Consider an airborne radar illuminates the ground surface as shown in Figure Q2.2.

(i) Prove that the Signal to Clutter Ratio (SCR) for area clutter can be written as

$$(SCR)_{A_c} = \frac{2\sigma_t \cos\psi_g}{\sigma^o R\theta_{3dB} c\tau}$$

[5 marks]

(ii) Let the antenna 3dB beamwidth be θ_{3dB} = 0.05rad, the pulse width τ = 5μs, range R = 10km, and grazing angle ψ_g = 30°. Assume target RCS σ_t = 2m^2, and clutter reflection coefficient σ^o = 0.05. Compute the SCR in dB.

[5 marks]

Continued ....

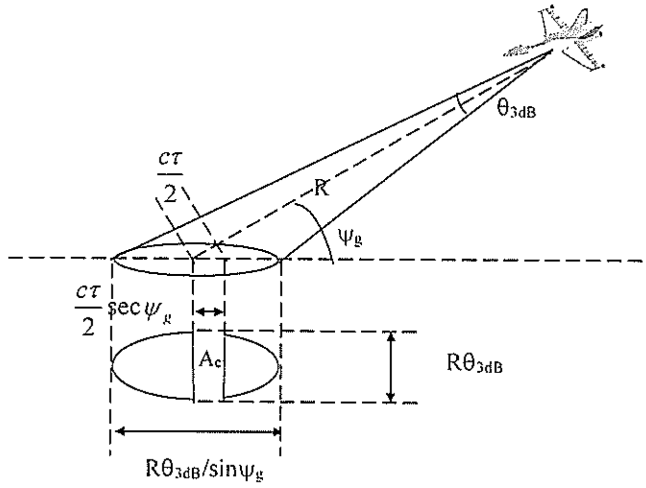

Figure Q2.2: Geometry of Airborne Radar System

Question 3

(a) An X-band pulse radar has the following specifications:

probability of detection $P_d = 0.95$
time of false alarm $T_{fa} = 6$ minute 40 second
operating bandwidth $B = 50$ MHz

The probability of detection versus single pulse Signal-to-Noise-Ratio (SNR) for several values of P_{fa} is shown in Fig. Q3.1. Assume single pulse processing.

(i) Compute the probability of false alarm P_{fa}.

[3 marks]

(ii) Determine the signal to noise ratio (SNR) at the detector's input.

[3 marks]

(iii) At what SNR would the probability of detection drop to 0.60 (with P_{fa} not changed)? Comment the finding.

[4 marks]

(iv) Assuming non-coherent integration of 10 pulses, what is the SNR reduction so that P_d remains unchanged? Refer Fig. Q3.2 for Improvement factor versus number of pulses (non coherent integration).

[6 marks]

Continued ....

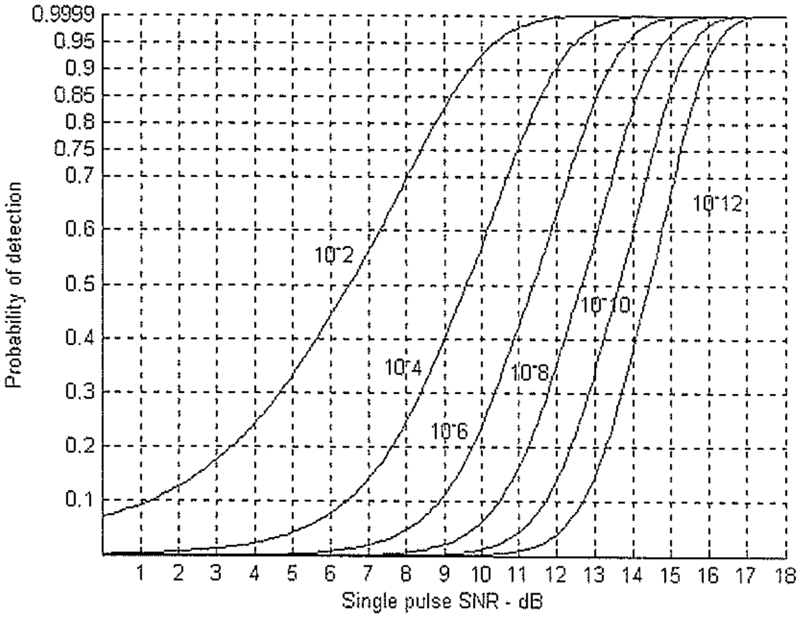

Fig. Q3.1: Probability of detection versus single pulse SNR for several values of P_{fa}

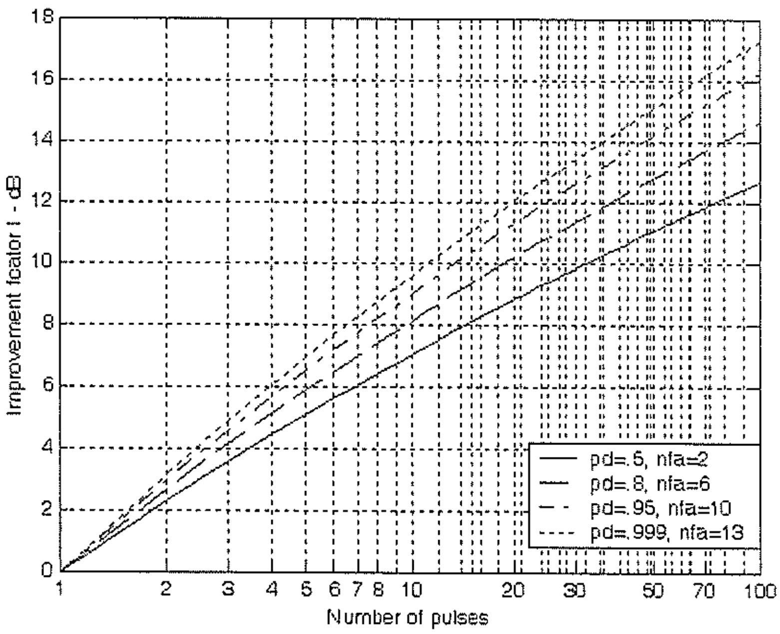

Fig Q3.2: Improvement factor versus number of pulses (non coherent integration).

Continued ....

(b) Fig Q3.3 (c) shows a receiver channel of a Radar System. The noise figure and gain of a LNA in a receiver is $F_1 = 1.5$ dB and $G_1 = 15$ dB. The noise figure and gain of a Band Pass Filter (BPF) in a receiver is $F_2 = 4.5$ dB and $G_2 = 0.1$ dB. The noise figure and gain of the MIXER in a receiver is $F_3 = 6$ dB and $G_3 = -0.5$ dB, respectively.

(i) Calculate the overall noise figure of this combination.

[3 marks]

(ii) Comment on the overall noise figure and noise figure of LNA alone and highlight the importance of LNA in typical radar receiver.

[4 marks]

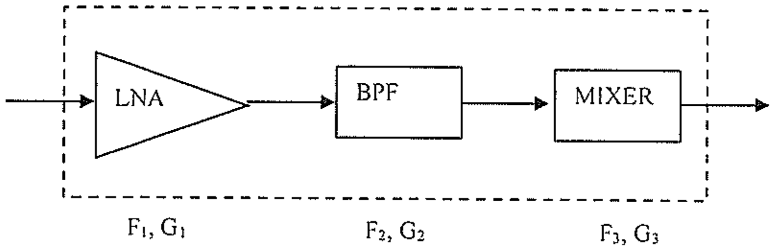

Fig. Q3.3 (c)

(c) You are required to design a radar system to perform range measurement. The range resolution requirement is 0.5m and the linear frequency modulation (LFM) waveform is to be implemented in this radar system:

(i) Propose a suitable bandwidth for this radar system.

[3 marks]

(ii) Propose a suitable sampling rate for the received return echo from the target for the bandwidth proposed in (ii).

[4 marks]

End of Page